LESSON 21 – APPLICATION EXERCISE 2
(Bring a 3.5" computer disk to class)
We'll analyze a variety of waveforms to break complicated waves into simple, single-frequency components

Reading:
Stimson **Ch. 5**
Problems/Questions:
Work on Problem Set 3
Objectives:
21-1 Understand how phasors can be used to represent EM waves.
21-2 Understand how phasors are used to analyze complex EM waves.

Last Time: E&M review
Waves
Decibels

Today: Phasors

Last lesson we started looking at the equation for an oscillation at a fixed point in space, $y = A \cos (\omega t + \phi)$. We saw that it was a plot of a sinusoidal wave that varied in time with amplitude A, angular frequency ω, and phase shift ϕ.

For our purposes today, perhaps the most important parameter of the wave will be the phase shift. Why? Let's look at how a radar works on the inside.

What is the frequency of a fighter radar? Remember, I told you the wavelength was about 3 cm. Using $c = \lambda f$, we can see that the frequency of such a radar is about 10 GHz. In order to produce and analyze radar signals, clocks of very high accuracy are needed. They create the signals that cause the variations in the wave to occur at the correct frequency. A signal of this known frequency is sent out from the radar. It bounces off a target and perhaps changes frequency slightly.

Frequency shift is directly related to velocity of the target, so we can determine target velocity. If the target is coming toward the radar, the frequency of the received signal is higher than the frequency of the transmitted signal; if it's moving away, the frequency is lower. If one target is moving toward the receiver toward the radar twice as fast as another target, its frequency shift will be twice as much. This is called the *Doppler Effect*, and we'll go into it in detail later.

Anyway, the received signal reaches the antenna and is then mixed with the reference signal that looks like a low-amplitude version of the transmitted signal. The mixed signal is then *sampled* by a digital computer *at a rate equal to that of the transmitted frequency*, and the beats are counted. The beat frequency is the amount the target-reflected signal differs from the transmitted frequency. The beat frequency is much easier to count than the transmitted frequency, as we'll soon see.

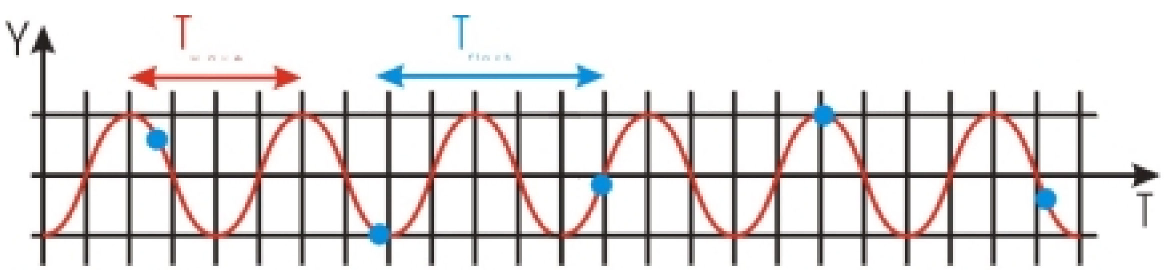
But that gets ahead of where we are. What we need to know is how this relates to phasors.

Show a rotating wheel with a piece of tape on it.

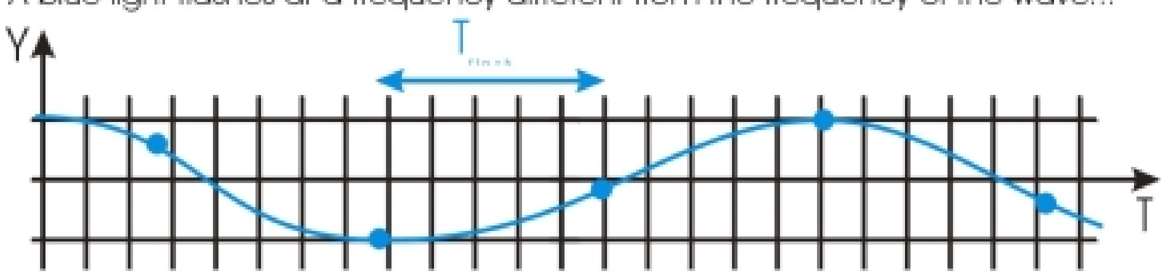
Show that as it rotates, if we plot y vs time, we get a sine curve. If we plot x vs. time, we get a cosine curve.

Have the cadets close their eyes and open them periodically to see the tape "standing still" as in a poor man's strobe light.

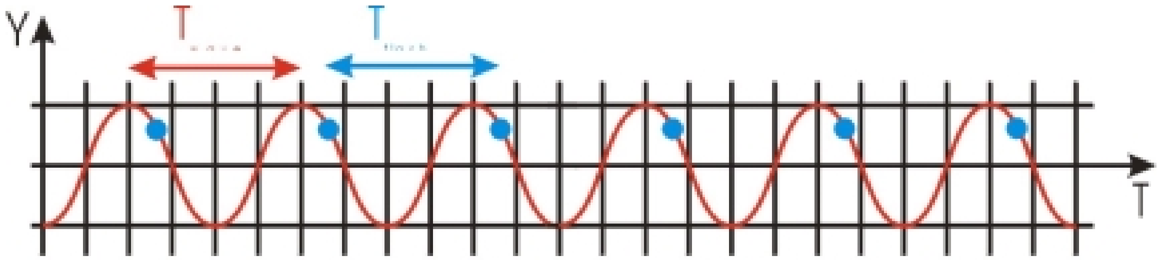
What we're doing by opening and closing our eyes is "sampling" the data at the frequency at which our eyes are opening and closing. Here's a plot of what sampling does:



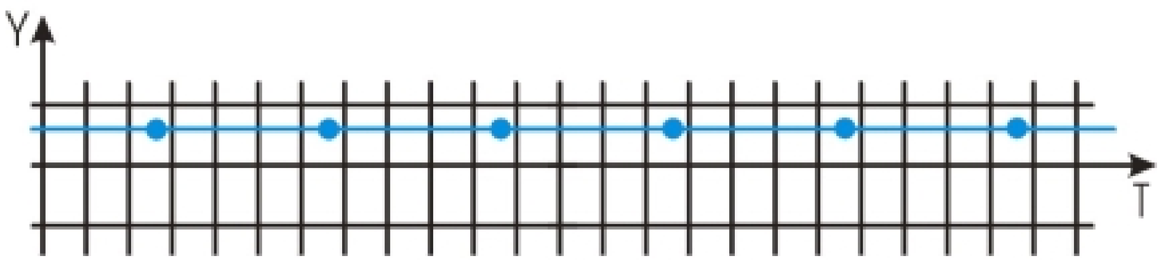
A blue light flashes at a frequency different from the frequency of the wave...



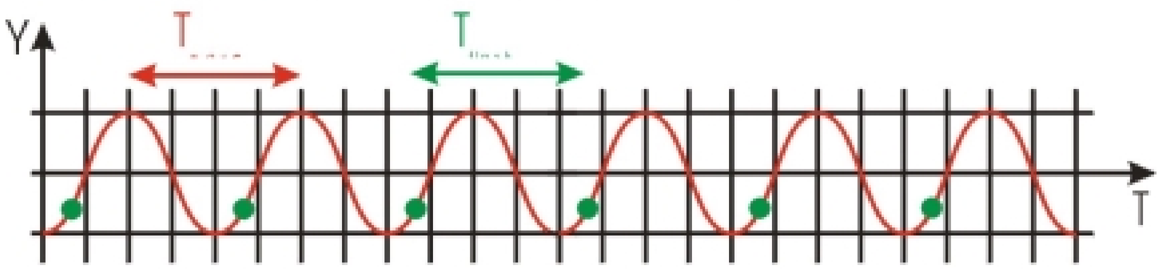
...Yields another wave that oscillates at a different frequency.



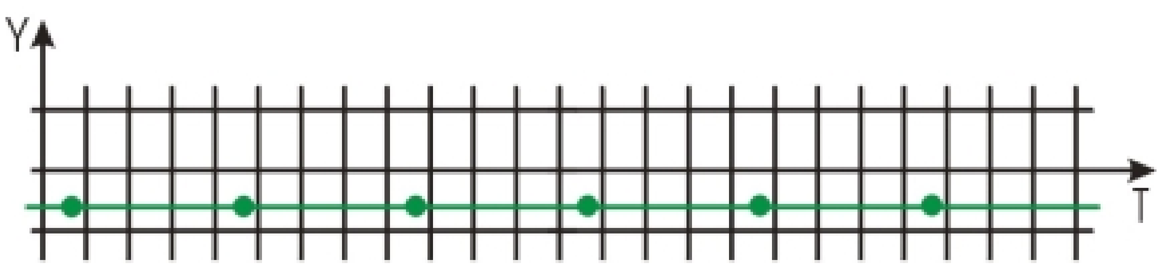
A blue light flashes at a frequency equal to the frequency of the wave...



...yields a horizontal plot that doesn't wiggle anymore.



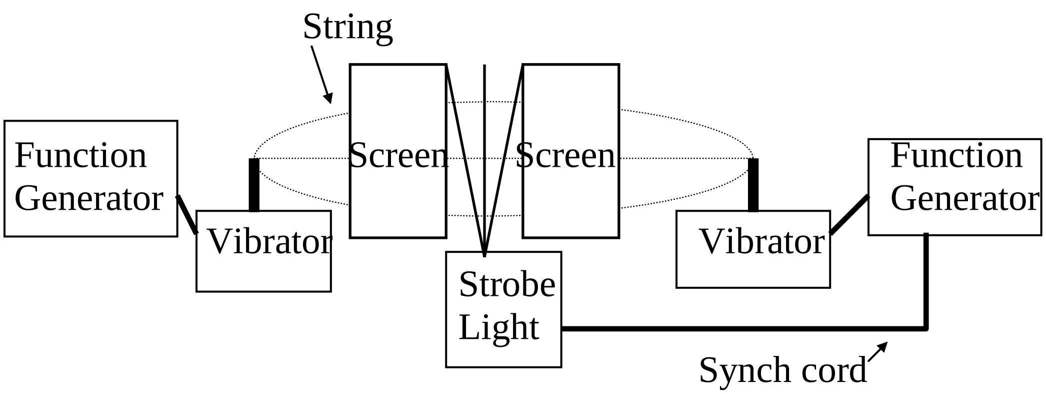
A green light also flashes at a frequency equal to the frequency of the wave...



...and also yields a horizontal plot that doesn't wiggle anymore, but with a different amplitude. This is true for any synchronized sampling rate.

Show standing wave demo

Set the frequency generators on a moderately fast rate so that with the overhead lights on it is impossible to count how fast they are moving.



Show that no matter what frequency the right function generator is set on, it appears to be stationary when the strobe is synched to it. This says that the sampling rate (the strobe flash) equals the frequency of the signal. The phase of the information (the position of the string) is a constant. If only the left function generator is on, the phase of the information changes. If BOTH function generators are on, this signal also changes with time and the change is related to the difference in frequencies of the function generators. If you know the frequency of the right function generator, you then know the frequency of the left function generator.

Can you count the changes by eye? It's lots easier to count the beats than the individual oscillations. Compare this to what happens in a radar. A signal of known frequency is sent out. It bounces off a target and perhaps changes frequency slightly. It is received by the antenna and mixed with the reference signal that looks like the transmitted signal. The mixed signal is then sampled by a digital computer at a rate equal to that of the transmitted frequency, and the beats are counted. The beat frequency is the amount the target-reflected signal differs from the transmitted frequency. Since frequency shift is directly related to velocity of the target, we can now determine target velocity.

But that gets ahead of where we are. What we need to know is how this relates to phasors. For that, we'll do a quick computer application.